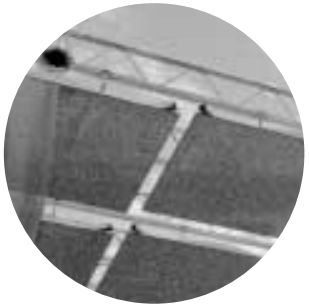

Sandia
PERSPECTIVES
2000
PROTECTING THE NATIONAL
INTEREST FOR 50 YEARS
Sandia
National
Laboratories
A Department of Energy
National Laboratory

Since 1949, Sandia National Laboratories has developed science-based technologies

that support national security.

Sandia PRIORITIES



On the cover - Looking back: A B61 missile prototype awaits testing on Sandia's rocket sled track in the 1960s. Today: A photonic crystal bends microwave signals around sharp corners. Looking ahead: Pollen-size micromachines will handle timing, sensing, and other tasks in the microelectronic systems of the future.

In the early years, research focused on nuclear weapons development, but as more nations have acquired weapons of mass destruction and original nuclear stockpiles have aged, Sandia's mission has broadened.

Today, to support the United States Department of Energy and, as appropriate, the Department of Defense, Sandia's primary areas of responsibility include nuclear weapons, nonproliferation and materials control, energy and critical infrastructure, and emerging threats. You will find this issue of Perspectives arranged accordingly. Also, we invite you to browse the history pages of this publication for highlights from the past 50 years of service to the nation.

If you need more copies of this brochure, please contact us at (505) 844-4902 or send e-mail to cimyers@sandia.gov

For further information about Sandia, please visit our Web site at www.sandia.gov

This page:
Sandia President Paul Robinson and Executive Vice President Joan Woodard examine a plasma chamber in Sandia's Plasma Processing Research Lab. Plasmas are hot gases used to clean the surfaces of weapon components to enhance adhesion. They are also used to etch circuits on microchips.

Facing page:
Energy Secretary Bill Richardson speaks with reporters during a visit to Sandia.

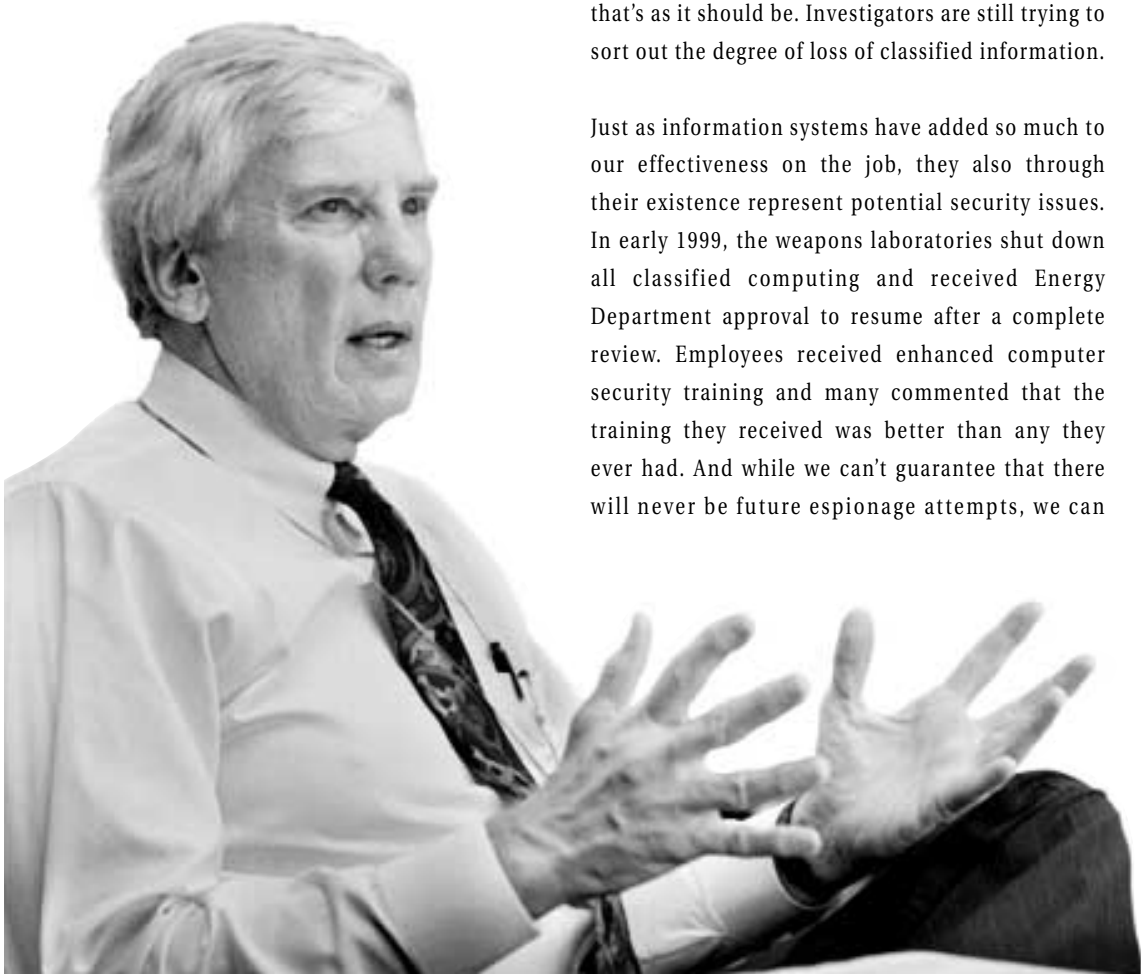
our focus

FOR THE NEW MILLENNIUM

Sandia President C. Paul Robinson and Executive Vice President Joan Woodard share their insights, look back over Sandia's first 50 years, and anticipate another 50 years.

Intellectual capital has always been a key component of Sandia's success. During the past year, we have seen evidence of this in the development of new optical techniques that may one day enable computers to run on light instead of electricity, a chemistry lab made of silicon chips and micromachines so tiny the whole system fits on a postage stamp, mobile robots that handle everything from battlefield surveillance to waste removal, and laser-based manufacturing techniques that reduce the time and cost associated with new product development. These are just a few examples of our recent accomplishments.

At the same time, allegations of espionage have dominated headlines and drawn our attention to an important problem that will require the cooperation of all of us. The possibility that China may have acquired key classified information about U.S. weapon systems has shaken the national laboratories and the



departments of Energy and of Defense. Though we have not been directly involved, Sandia has been treated — and rightly so — with the same scrutiny as all the nation's weapons laboratories. This incident serves as a wake-up call for all of us. We take no comfort in the fact that the problems to date have been at other laboratories. All of the same rule changes have been imposed on us, and that's as it should be. Investigators are still trying to sort out the degree of loss of classified information.

Just as information systems have added so much to our effectiveness on the job, they also through their existence represent potential security issues. In early 1999, the weapons laboratories shut down all classified computing and received Energy Department approval to resume after a complete review. Employees received enhanced computer security training and many commented that the training they received was better than any they ever had. And while we can't guarantee that there will never be future espionage attempts, we can guarantee that Sandia is working hard to implement long-term solutions for the security of the nation's classified information.

OUR STRATEGY FOR THE FUTURE

Looking ahead to the year 2000, we believe we will make even greater improvements to computer security as well as in other areas by continuing to focus on what we do best — meeting the science and engineering challenges of managing the nuclear weapons stockpile. This is a mission that spans every technical discipline. More than 272 million Americans depend on Sandia for the safety, security, and reliability of the nuclear weapons stockpile. We believe our performance in achieving this mission is ultimately what enhances the value of taxpayers' investment in Sandia.

We will continue our work in improving the security of information systems. Recently, we unveiled the "world's smallest combination lock," a microscopic mechanical device developed with circuit-printing technology at Sandia's Microelectronics Development Laboratory. This device may in the future prevent hackers from gaining access to sensitive computer files. Practically invisible, the device contains silicon wheels the size of the period at the end of a sentence in a standard newspaper. The device will operate only if the correct code is entered.

We will continue to provide system support for satellites that "wage peace" through arms control and verification. The Multispectral Thermal Imager scheduled for launch later this year will demonstrate new, more powerful technologies for identifying suspect sites involved in producing weapons of mass destruction. It will collect important data for environmental and climate research.

And we will continue to make progress in the national effort sponsored by the Department of Energy to develop a "chemistry laboratory on a chip" that sniffs out explosives and chemical warfare agents. Already the prototype chemistry lab, made on silicon chips, is smaller than a postage stamp.

We will continue to pursue the goal of making computers smaller, faster, and more powerful. The Double Electron Layer Tunneling Transistor (also known as the quantum-well transistor) is expected to operate at roughly 10 times the speed of the fastest transistor circuits now in use. Photonic crystals that bend infrared light or microwaves around 90-degree corners without leakage may one day enable computers that use light energy instead of electricity.

Our California site will continue to host the largest government-industry partnership to date, a $250-million consortium that includes three national laboratories, Intel Corporation, Motorola Corporation, and Advanced Micro Devices. Equipment and component suppliers include Silicon Valley Group Inc., Northrop Grumman, TRW, Ultratech Stepper, Micron Technology Inc., and a Dutch corporation, ASM Lithography. These companies are working with Sandia, Lawrence Livermore, and Lawrence Berkeley national laboratories to use extreme ultraviolet lithography to produce microprocessors that are 100 times more powerful than those of today and memory chips that can store 1,000 times as much information.

We will continue our focus on partnerships with industry and other laboratories. Three business partners have moved into the Sandia Science and Technology Park, a business park adjacent to Sandia in Albuquerque, New Mexico. They include EMCORE, a compound semiconductor manufacturer; Microdexterity, which specializes in medical robotics for surgery; and CSTI, a telecommunications company.

We will continue our partnerships with universities. Last year, we spent $25.8 million on research collaborations with universities nationwide.

Our collaboration with NASA continues. At this very moment, a surface-penetrating probe developed at Sandia is on its way to Mars to look for evidence of water or ice beneath the surface. NASA is planning an upcoming space shuttle mission that will map the surface of the Earth using synthetic aperture

> We can never tell you that we don't have a spy ... we can't know what we don't know. We have certainly turned up the vigilance associated with counterintelligence to a higher level than before.

C. Paul Robinson, president

> I've had lots of experiences — multiple jobs over my 25-year career at the laboratory. A number of people took a risk with me. We need to allow that. We need to encourage people to take those risks because the good people will spin up very quickly; they'll probably wow your socks off.

Joan Woodard, executive vice president

radar developed at Sandia. This technology uses massively parallel processing to analyze huge amounts of data and produce radar images with unprecedented detail and precision.

We think you'll agree that Sandia is a strong, diverse laboratory that is well prepared to enter the 21st century. Though we remain constant in size, our budget is growing at approximately 3 percent per year, about the rate of inflation, and we are predicting moderate growth in income through the year 2000. We spent about $1 billion in New Mexico during fiscal year 1998 and $400 million in California and other states on salaries, purchases, health care costs, contract labor, and retiree benefits. We plan to hire 215 technically qualified people to fill science and engineering jobs in the coming year.

Beginning this fall, we will also improve the efficiency of our financial, property and personnel recordkeeping when we switch to a single system. From then on, we will have only one set of books managed by commercial software rather than several independent accounting systems.

ENVISIONING SANDIA AS THE EMPLOYER OF CHOICE

Because Sandia's work force is aging, we continue to hire new recruits within two or three years of earning college degrees. Revitalizing our work force and managing knowledge preservation and continuity is a priority. Sandia's turnover is driven largely by retirements, and many of our retirees remain in New Mexico and California. Sixty percent of our new hires last year were recent college graduates, and this year we're setting our sights even higher. When we have had opportunities to hire truly outstanding graduates, we've gotten them. That may be the best metric as to whether Sandia is an employer of choice.

We continue to diversify the opportunities available to staff members to accomplish some of their work by telecommuting and by working flexible hours.

Sandia places great value on the diversity of our staff. This was true before the allegations of Chinese spying, and it remains equally true today. We will not tolerate the mistreatment of loyal Americans within the laboratories. We completely support the statement of Energy Secretary Bill Richardson affirming equal rights. We should judge people as individuals, not by class or race.

Our commitment to diversity is reflected in the makeup of our upper management. In recent years, we have appointed women and minorities to fill several positions as vice presidents, directors, and executive vice president. While there will always be room for improvement, we continue to make progress in this area.

HERE'S TO THE FIRST 50 AND THEN TO 50 MORE

Imagine the following scenario:

It's 1943, two years before the first atomic bomb is tested at the Trinity Site on July 16, 1945. Brig. Gen. Eugene L. Eubank, for whom Eubank Boulevard in Albuquerque will be named, emphasizes the importance of the individual soldier in a war movie titled "*Bombardier*." The movie is filmed in part at Kirtland Air Force Base. The general does not yet know just how important the responsibility will be that is placed in the hands of the pilot and bombardier. This responsibility will form the basis of all of Sandia's work in the future.

Today the soldier is sometimes a woman. And the "greatest responsibility ever placed upon an individual soldier" also applies to the individual design engineer, who has the job of making sure that a nuclear weapon will hit the target and work reliably, and only when intended and not by accident. This has been Sandia's mission ever since the Manhattan Project and it remains our primary mission today. We call this mission surety, a word that takes in all aspects of safety, security, and reliability.

Sandia's 50th anniversary officially takes place Nov. 1st. We have scheduled three days of special events to commemorate the occasion.

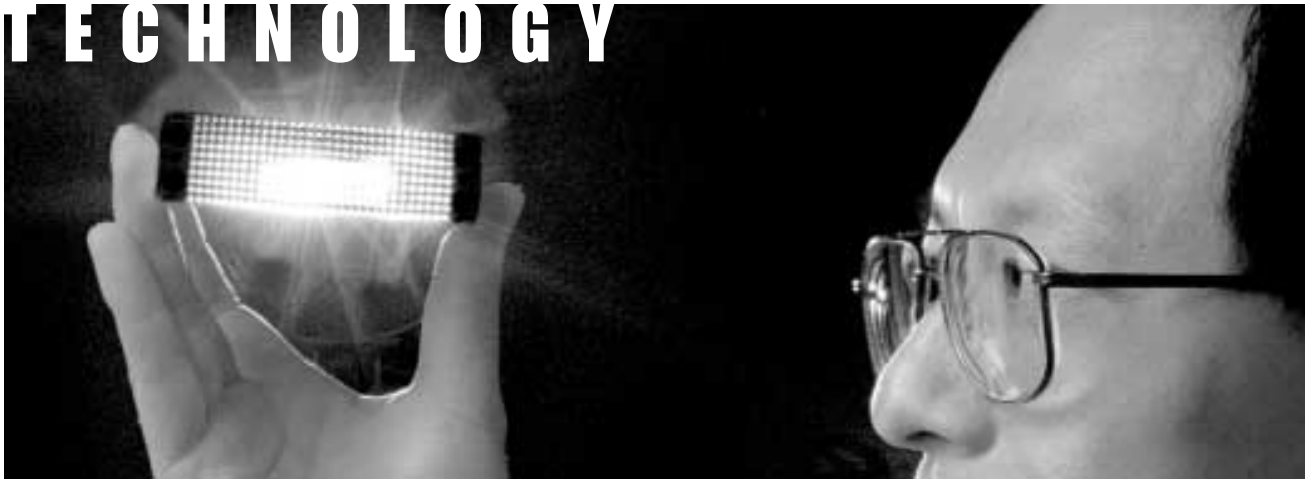
It's hard to say in any age whose challenges are greater — Sandia's in the 1940s or those we face today. The security challenges of the modern world are different because they reflect a different mix of technology. Today's security challenges include counterterrorism, nonproliferation, energy security, and environmental protection. Sandia's role has broadened to address all these challenges.

But just as Gen. Eubank noted when he stressed the importance of a single individual, the bombardier, we find that it takes a great many individuals, dedicated to working together, to achieve success. It takes people to look at a situation, think about it, come up with a solution, and go the distance to make it happen.

It is a pleasure to work with Sandia's employees every day in developing the technologies that the nation needs for peace and prosperity. During the past 50 years, we have made a real difference in the security of Americans. It's our hope that, for every second of the next 50 years, we will continue to be ready when called upon to render — in those immortal words of Harry Truman when he established Sandia in 1949 — "...exceptional service in the national interest."

new ideas & partnerships
ARE TRANSFORMING

WEAPONS TECHNOLOGY



Shawn Lin holds a prototype photonic lattice that is revolutionizing the ways engineers can use light.

Light — in rays. Straight.

Now, imagine light turning corners. Actually, we no longer need imagine this phenomenon; we can begin to reap its benefits. It became reality in 1998 with a Sandia National Laboratories collaborative breakthrough, the photonic lattice.

This technology represents a new mechanism for controlling light. A benchmark in physics and engineering, the photonic lattice resulted from a Sandia partnership with Ames National Laboratory, a Department of Energy facility at Iowa State University. The photonic lattice offers one recent example of the new "light" Sandia partnerships can shed on the future of science and technology.

Partnerships bolster the four primary Sandia responsibilities

NUCLEAR WEAPONS

Ensuring that the stockpile is safe, secure, reliable, and capable of supporting the nation's deterrence policy.

NONPROLIFERATION AND MATERIALS CONTROL

Reducing the proliferation of weapons of mass destruction, the threat of nuclear accidents, and damage to the environment.

ENERGY AND CRITICAL INFRASTRUCTURES

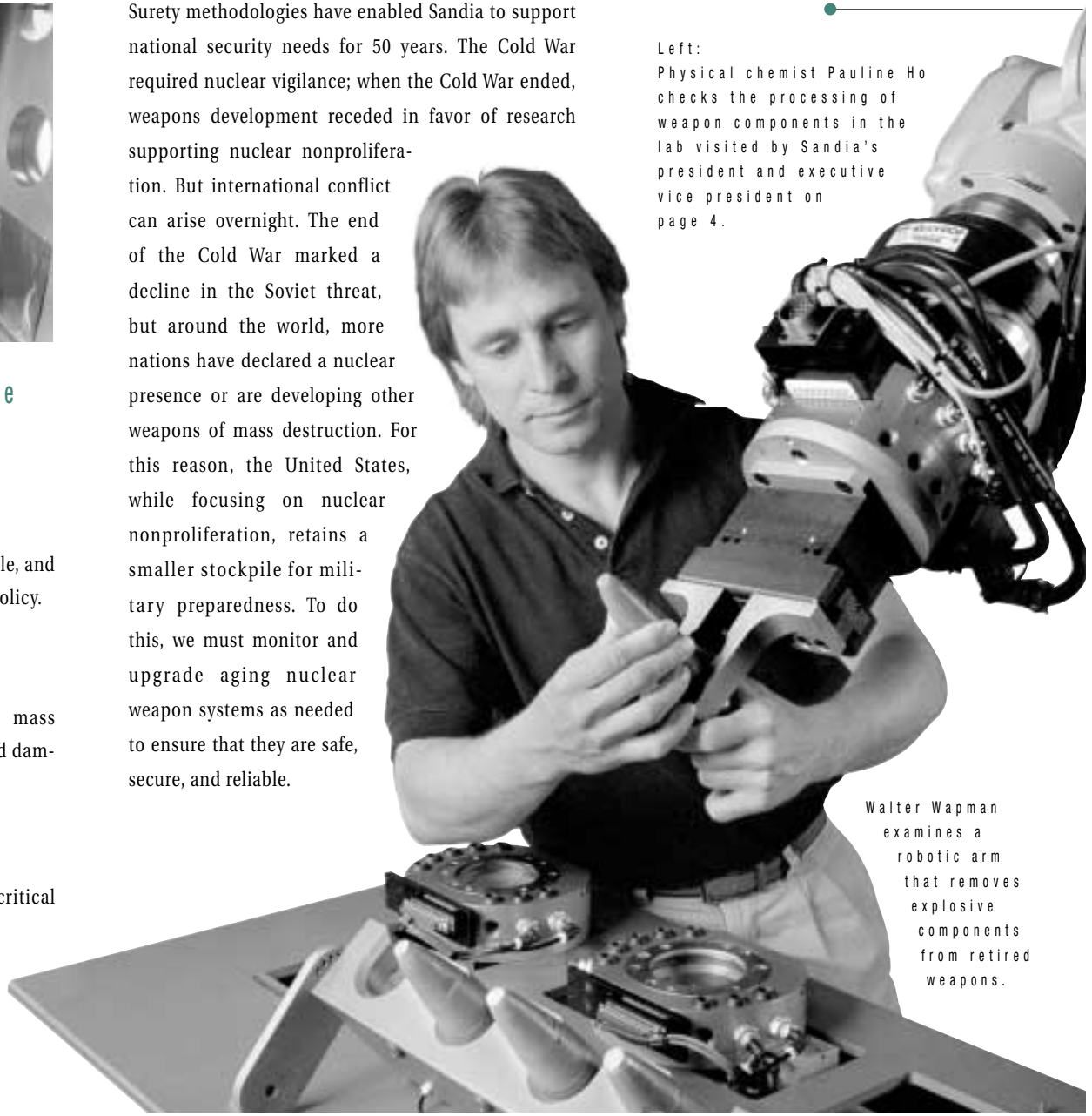
Enhancing the surety of energy and other critical infrastructures.

EMERGING THREATS

Addressing new threats to national security.

Surety methodologies have enabled Sandia to support national security needs for 50 years. The Cold War required nuclear vigilance; when the Cold War ended, weapons development receded in favor of research supporting nuclear nonproliferation. But international conflict can arise overnight. The end of the Cold War marked a decline in the Soviet threat, but around the world, more nations have declared a nuclear presence or are developing other weapons of mass destruction. For this reason, the United States, while focusing on nuclear nonproliferation, retains a smaller stockpile for military preparedness. To do this, we must monitor and upgrade aging nuclear weapon systems as needed to ensure that they are safe, secure, and reliable.

Left:
Physical chemist Pauline Ho checks the processing of weapon components in the lab visited by Sandia's president and executive vice president on page 4.



Walter Wapman examines a robotic arm that removes explosive components from retired weapons.

Micro is BIG

Through surety-related partnerships, Sandia is building a small world. And that represents a huge undertaking. Sandia is a world leader in developing intelligent microsystems that will soon be able to sense, act, "think," and communicate. Already their precursors are making ink-jet printers and compact-disk players reliable and affordable. Already sensor technology is inflating automotive airbags and saving lives. Affordable, reliable microsystems are ubiquitous.

Surety — There's No Getting Around It ...

The nuclear age has made one immutable demand: prevention. And preventing nuclear war imposes a second requisite: surety — that is, safety, security, and reliability of the nuclear stockpile. These attributes are at the heart of Sandia's research.

Surety as a discipline has evolved from five decades of group effort and partnerships. So pervasive in their applications today, surety methods have emerged whenever engineers and scientists from government, academia, and industry have shared ideas, learned what works, and developed solutions and new technologies — from safer cars to a safer nuclear-age world.

In October 1998, Sandia put surety as a discipline to the test. We hosted a workshop to share our surety-based methodology with scientists and engineers from industry. Workshop participants agreed that surety practices Sandia has developed during 50 years of weapons work promise benefits in research and development across industry lines.

> The world presence of weapons of mass destruction demands prevention. Prevention demands surety. Surety demands collaboration. And what may be the keystone challenge — nonproliferation — in the history of civilization will be met in no other context than partnership.

... and Most Americans Agree

Americans want surety, too. A national Sandia-sponsored survey conducted in 1997 by the University of New Mexico revealed that a majority of Americans, U.S. legislators, and scientists perceive a continued nuclear threat and want the nuclear stockpile maintained to safeguard the nation.

The study revealed that 64 percent of those surveyed had concerns about the Chinese nuclear threat, the likelihood of nuclear terrorism, and the aging of nuclear stockpiles worldwide. Most survey participants responded that it was either more important or just as important today for the United States to maintain its nuclear weapon capabilities as in 1993, when a baseline survey was conducted. The 1998 participants considered it unlikely that nuclear weapons would be eliminated worldwide in the next 25 years and believed that, even if such weapons were eliminated, more nuclear arsenals would be developed in other countries.

The majority of survey participants did not advocate eliminating U.S. nuclear weapons, but they also did not favor developing and testing new weapons. Instead, they supported stockpile stewardship that focuses on safety, reliability, and training.

The majority of those surveyed also favored U.S.-Russian partnerships directed at nonproliferation and environmental cleanup.

Paul McWhorter is dwarfed by a magnified image of a micromachine so tiny it can only be seen through a microscope.

This page:
Victor Baca slides a tray of neutron generator tubes into a dessicator cabinet.

Facing page:
Glen Heston checks a 1,300-pound insulating ring from Sandia's Z machine, an accelerator used for fusion research.

W76 Neutron Generator Recertification Program Helps the UK

For 50 years, Sandia research has developed safeguards to prevent accidents, deter attacks, and monitor nuclear weapon development worldwide.

W76 is the name of a weapon system that must be periodically tested and reconditioned. Sandia accepted responsibility for production of neutron generators, a W76 component, for the Department of Energy in 1994. Since then, the Sandia team has met or exceeded DOE and Department of Defense requirements for product performance, timely delivery, and cost reductions. As a result, Sandia is now on schedule to meet its nationally publicized corporate objective of building and delivering neutron generators to the Department of Defense by October 1999. And the Sandia program that carries out this task has been so successful, the United Kingdom has invited Sandia to recertify some of its neutron generators.

The process has three steps: First, the mounting hardware and the timer-driver are removed from the neutron generator and all are cleaned, inventoried, packaged, and sent to the appropriate Sandia facility for testing. Second, the generator is X-rayed, cleaned, and inspected for damage that might have occurred during step one. The devices are tested for neutron output and stamped when they pass inspection. Third, a new timer-driver is installed on the neutron generator and marked with identification and serial numbers. After a final inspection, the recertified weapon is returned to military storage.

In a similar effort, the DOE and the U.S. Navy are collaborating on a program to maintain capabilities related to submarine-launched ballistic missile warheads. This program is called the Submarine-Launched Ballistic Missile Warhead Protection Program.

DOE Laboratories Solve Safety Issues

The DOE's three nuclear weapon labs — Sandia, Los Alamos, and Lawrence Livermore — are racing the clock to "see" inside weapons. That's because in the absence of nuclear testing, they must invent new ways to ensure nuclear weapons are safe, and the techniques used must be fast, inexpensive, and reliable.

The easiest way, detonating bombs, is not allowed. The Sandia team is using pulsed power, a method for containing and releasing energy in bursts that can flash a picture of what is inside a bomb — an X-ray of sorts. The process is called radiography. Sandians plan to design a system providing an almost three-dimensional view of the bomb's innards. They plan to use beams of atomic particles to provide views of bomb interiors.

Z Machine Sizzles

No energy shortage here. The Z machine (formerly called the Particle Beam Fusion Accelerator) has produced 290 trillion watts — 80 times the world output, for five billionths of a second — as it closes in on the ever-elusive goal of sustainable fusion.

The world's most powerful X-ray source, the Z has reached a toasty 2.0 million degrees Celsius, at the leading edge of the 2 million to 3 million degrees believed to be necessary for nuclear fusion. These temperatures are comparable to those inside the sun, and fusion is the process that powers the sun.

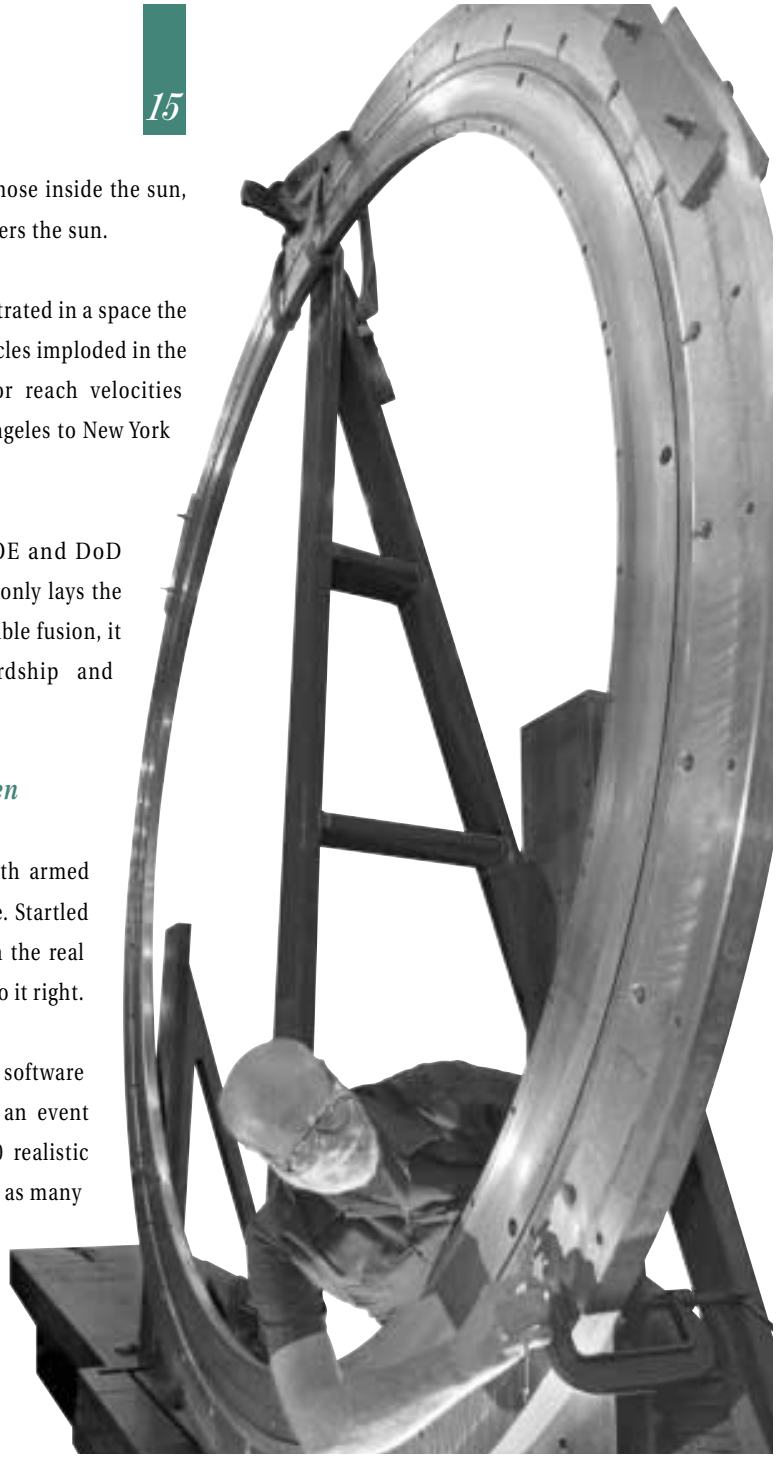
Energy in the Z machine is concentrated in a space the size of a spool of thread, and particles imploded in the tiny target inside the accelerator reach velocities that would fly a plane from Los Angeles to New York in one second.

The research, conducted at DOE and DoD laboratories and universities, not only lays the groundwork for achieving sustainable fusion, it also supports stockpile stewardship and advances basic science.

Combat Simulator to Sharpen NATO's Edge

It could happen: An aggressor with armed cohorts penetrates a NATO airbase. Startled NATO personnel must respond. In the real world, they'd have one chance to do it right.

Sandia's joint tactical simulation software allows trainees to simulate such an event and practice their response to 30 realistic scenarios — and not just once, but as many times as needed. Sandia uses the software for security evaluations and training at DOE and DoD sites nationwide. The software



"Your work helped save a $20 million satellite communications program here at Hughes."

— Dan Goebel, Hughes Electron Dynamics, Torrrance, California

models terrain, weather, lightning, and weapons capabilities. Maps and photographs provide data for detailed models of buildings, walls, forests, and rivers that respond to the impacts of human activity the way they would in real life. And unlike actual rehearsals, JTS allows numerous variations in a short time span, at little cost, and without environmental damage or harm to participants.

The effectiveness of NATO responses can thus be immediately evaluated through lifelike simulations. And this allows NATO to revise or refine training exercises as needed.

Micro Guardian Has a Mega Mission

To prevent accidental detonation of nuclear weapons, Micro Guardian will put several micromachines on a chip. This design integrates microelectronics, micro-optics, and micromechanics into a single system. The result will be a subsystem that will allow detonation only after an exact series of events. And the technology will, indeed, be tiny — mere millimeters in size. Micro

Right:
Beth Potts views Micro Guardian, a new safety subsystem for nuclear weapons. It is the most complicated microsystem Sandia has ever developed. The technology incorporates micromachines, microelectronics, and micro-optics all on one chip.

PARTNERSHIP moves technology *to the* marketplace

Sandia is partnering with Optomec Design Company in Albuquerque, N.M., to commercialize laser-engineered net-shaping technology, known as LENS for short. As a member of a 12-company consortium, Optomec has access to Sandia equipment for testing and quality control of components produced with LENS. When very small lots are needed, Optomec can provide — without the associated prototyping and manufacturing development costs — replacement parts for weapon systems.

In the LENS rapid prototyping and rapid manufacturing system, computer-controlled lasers fuse metallic powders into custom parts and manufacturing molds. The advantage of the technology is that it allows the creation of small lots of customized parts. Dissimilar materials can be fused together to change the composition of new parts. The resulting strength of LENS materials is twice that of traditionally annealed stainless steel parts, yet the parts have the same ductility as steel and cooling cycles for producing them are shorter.

In addition to defense applications, LENS has been used to produce tire-tread molds that are stronger than other molds, as well as engine turbines, car parts, plastic door handles, cookie molds, and other products.

In 1998, Optomec sold three LENS systems totaling more than $1 million to Sandia, Lockheed Martin Corporation, and Ohio State University. Sales for 1999 are already valued at approximately $1.7 million. Many of Optomec's customers are out of state, bringing new revenues into New Mexico, and the company provides jobs for more than 30 local employees, including university graduates.

Because defense needs are so specialized, Sandia is interested in low-volume production capabilities for highly specialized nuclear weapons components. The LENS technology allows more flexibility in designing parts. New methods are now being developed for the production of neutron tubes and generators and self-lubricating parts.

Guardian will replace 20-year-old technologies that take up more space inside a weapon and are costlier to produce.

Radiation-hardened Pentium Processor, Sandia & Intel Aligned

A Sandia-Intel partnership is once again bringing out the best in both. Intel's Pentium chip is about to become more indestructible. Sandia is hardening the microprocessor to survive high-radiation environments, such as those encountered by satellites in deep space. Sandia will do this by using unique metal-deposition technology developed at its Microelectronics Development Laboratory to strengthen nuclear weapons.

Intel granted Sandia a fee-free license, saving taxpayers millions of dollars. Other federal agencies are rallying behind the research. NASA's Jet Propulsion Laboratory, the Air Force Research Laboratory, and the National Reconnaissance Office are uniting to provide four years of funding for the technology. Partnerships such as these are a vital part of Sandia's goal to put the best technologies and business practices to work for national security.

Above:
Raymond Layba checks the precision manufacturing of new parts with Laser Engineered Net Shaping, a technology that is being commercialized by Optomec Design Co.

nonproliferation: APPLYING DEFENSE RESEARCH to ECONOMICS & peace

Before the nuclear age, people built weapons to use. Today, as the world amasses weapons of mass destruction, people everywhere hope these armaments will never leave storage. This marks a turning point for humanity and a colossal incentive for peace, the greatest of all partnerships.

Sandia was the first to bring satellite communications into former Russian secret cities. Pictured here are Paul Robinson and Al Zelicoff during a videoconference with Chelyabinsk and Arzamas.

Sandia Trains Russians to Meet Human-Resource Challenges

Last year, Sandia continued working with Russian nuclear laboratories to protect the safety and security of nuclear materials and convert defense activities into economically viable, peaceful applications. Out of this relationship came a number of productive collaborative initiatives, such as research on hepatitis C with the New Mexico Department of Health.

Human-resource specialists from Sandia held a four-day workshop last fall to help Russian scientists tap post-Cold War research opportunities. Russian laboratories have experienced staffing problems as a result of economic, political, and philosophic upheavals that inhibit scientists' ability to carry out their work.

Sandia held the event at a once-secret location called Chelyabinsk-70, then staged a one-day recap at a second research institute in Moscow. The workshop addressed the transition from weapons design to dismantlement and technology transfer. It also taught skills that U.S. laboratories consider essential — such as employee recruitment, use of the Internet, and development of a human-resource database. Russians previously used hands-on, labor-intensive techniques; they now understand how to use technology to accomplish such tasks. Participants said the workshops enhanced U.S. national security by stabilizing the Russian research community.

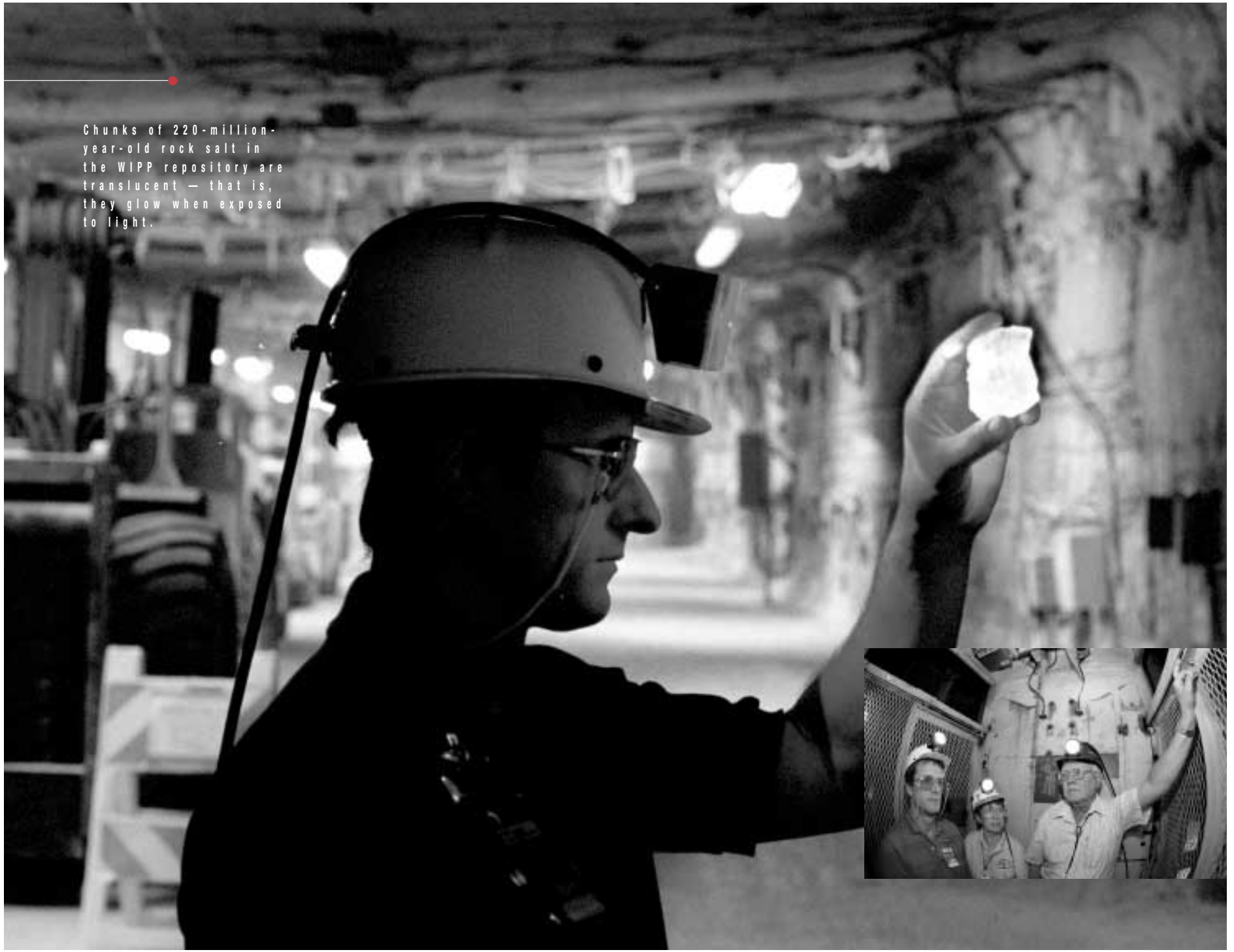
Cooperative Monitoring Advances Global Security

In support of arms control and nonproliferation, Sandia's Cooperative Monitoring Center encourages the use of technology to avoid regional conflict. The CMC hosts experts from around the world who learn to use technologies to track regional conflicts and monitor nuclear materials. Examples of these technologies are satellite transmissions, ground sensors, and on-site inspection systems.

Sandia also hosted the 10th Annual International Arms Control Conference. Guest speakers included Richard

Left:
The Center for National Security and Arms Control opened in 1997.

Below:
Mobile robots developed at Sandia can be used to improve the security of weapons or other sensitive materials and can be controlled over the Internet. Sensors and monitoring systems will eventually enable them to conduct remote inspections of hazardous areas.



Chunks of 220-million-year-old rock salt in the WIPP repository are translucent — that is, they glow when exposed to light.

Butler, the Australian-born head of the United Nations Special Commission on Iraq, and Bill Richardson, who was then Ambassador to the United Nations and is now Secretary of Energy. Conference participants visited the Cooperative Monitoring Center, located outside the secure area where Sandia conducts classified work. They learned about techniques for protecting nuclear materials, such as those used at civilian nuclear power plants.

Understanding the Threat

At the heart of Sandia's mission is a goal to wage peace. Weapons are designed with the hope they will never be used.

Inside Sandia's secure area, the Center for National Security and Arms Control has some of the most secure facilities in the world for studying and understanding the threat of weapons of mass destruction being developed around the world. The 85,000-square-foot facility features resources for planning and management of nuclear weapons activities; on-site inspection and cooperative validation of arms-control treaties; and threat assessment activities using real-time secure communication.

Destroying Destructive Materials

Old munitions, some dating back to World War I, can become unstable over time and remain a global threat. Sandia's Explosive Destruction System is reducing that hazard. The system destroys explosive charges within aging chemical weapons inside a confinement vessel that contains the blast, fragments, and gases that are emitted. This technique protects the environment as it eliminates a threat to human safety.

The Waste Isolation Pilot Project WIPPs into Action

After 25 years of work, the first load of low-level radioactive waste traveled from Los Alamos National Laboratory to the Waste Isolation Pilot Project outside Carlsbad, N.M. in the wee hours of March 26.

Sandia has been central to ensuring low-level waste is safely stored in 220-million-year-old salt beds of southeastern New Mexico. Sandia geologists and engineers have studied site selection, developed conceptual design, generated an environmental impact statement, tested transportation technologies, and provided physical data and performance predictions based on modeling and simulation. The environmental assessment concluded that no natural geologic or hydrologic processes could breach the repository for millions of years.

Above left:
Research at Sandia is transforming military Humvees into autonomous robots that can conduct environmental restoration.

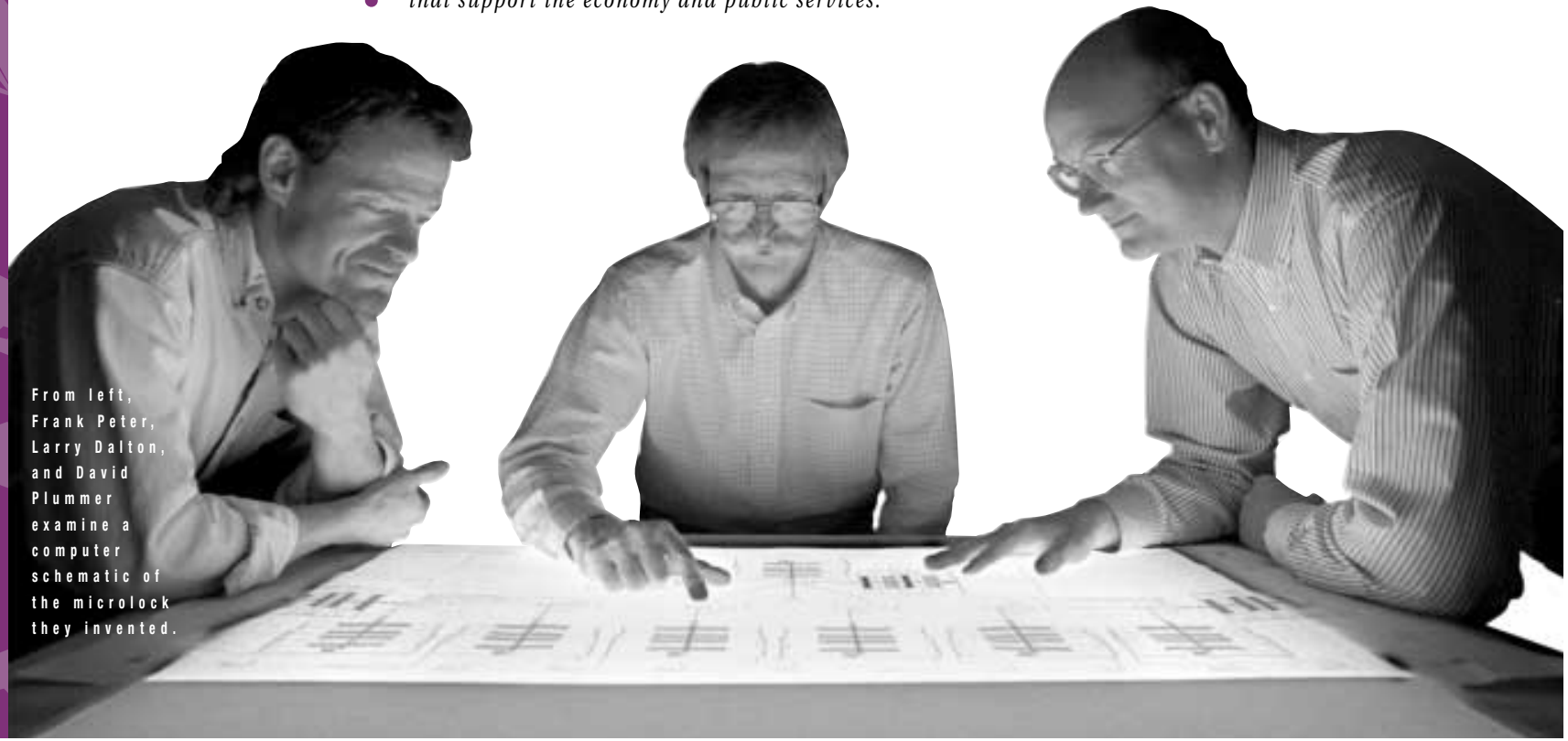
Above right:
The Explosives Destruction System is being used to destroy munitions in the U.S. and Great Britain.

Inset photo left:
Cliff Howard, Carla Mewhinney, and Wendell Weart descend into the WIPP repository 2,150 feet below the surface.

energy & critical infrastructures:

KEEPING the COUNTRY RUNNING

America's lifeblood is the modern network of infrastructures that support the economy and public services.



From left, Frank Peter, Larry Dalton, and David Plummer examine a computer schematic of the microlock they invented.

Critical infrastructures refer to a complex set of subsystems that include:

- Transportation
- Telecommunication
- Electric power
- Banking and finance
- Water
- Emergency services
- Oil and gas
- Government.

The loss of any of these systems would compromise activities on a broad scale. These subsystems have become increasingly interdependent, making the unified infrastructure increasingly vulnerable to error, attack, malfunction, and natural disaster.

To meet the challenge of keeping everything running safely and smoothly, Sandia has developed a consequence-based methodology to assess risk and reliability. The methodology identifies potential causes of failure and protection strategies.

MicroLock Wins 1999 Discover Award for Technological Innovation

Computer break-ins cost Americans big bucks every year and put confidential records at risk. Sandia's new microlock offers improvements on both counts.

Having gears nearly invisible to the naked eye, the world's smallest lock stores combination codes. It is virtually impossible for a hacker to circumvent the lock. Unwelcome visitors have one chance only to break in, and even then they face one-in-a-million odds against guessing the code. The computer will not allow additional access until the lock is reset, and the lock can be reset only when the authorized user enters a new code.

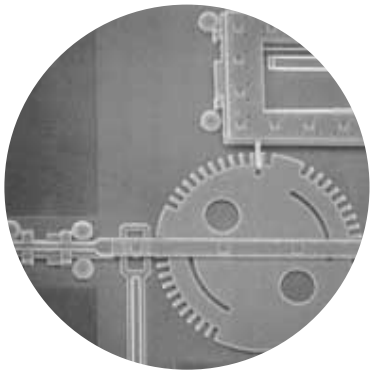
FAA Partnership Makes Air Travel Safer

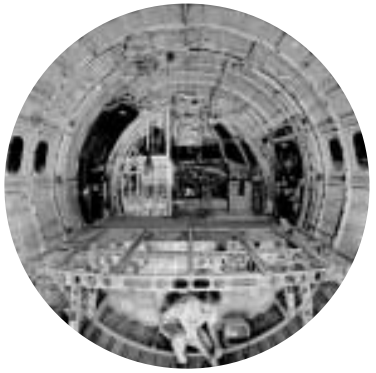
Every flight flawless — all airline passengers expect a smooth, safe ride between take-off and landing. And why not? Who has more at stake?

Sandia and the Federal Aviation Administration are working together to design a systematic approach to aircraft safety. The alliance strives to help 3,500 FAA airline inspectors track safety trends and spot potential problems in the aging U.S. fleet.

Former FAA inspection methods relied heavily on individual expertise. The inspection process was not systematic, and it focused on compliance with federal regulations.

After decades of inspecting weapons for safety, Sandia has developed a systematic, data-driven inspection methodology. Applying these principles to airline inspection, the FAA can anticipate meeting the national Safer Skies program goal of reducing accidents by 80 percent during the next decade.





Top:
The recodable microlock uses code wheels the size of a period in a standard newspaper.

Bottom:
Mike Valley inspects the fuselage of a DC-9 as part of a project with the FAA to improve the safety of aging aircraft.

Pete Witze operates a specially instrumented engine that allows optical studies of fuel injection at the Combustion Research Facility in Livermore, California.

Expanded Partnerships in Combustion Research

A $20-million Department of Energy grant has expanded Sandia's Combustion Research Facility in California and doubled its experimental capabilities in both basic and applied science.

For 20 years, the CRF has attracted scientists from industry and government who study combustion, the process that provides nearly 85 percent of U.S. energy. Sandia recently hosted business leaders from nine California counties at the CRF for a meeting on future economic development.

The expanded CRF features new diagnostic capabilities and an imaging laboratory that is three times larger than before. Research will focus on diesel fuel technologies, such as industrial techniques for producing synthetic hydrocarbons and for making diesel fuel from vegetable oils. And scientists will continue to observe flames inside an engine and measure the chemical species produced. Other studies will focus on submicron-size metal particles deposited inside combustion waste stacks.

DOE Partnership Provides Energy for Remote Arctic Villages

It's dark. It's winter. It's Fairbanks. What better place than Alaska to test a hydrogen-powered fuel cell?

Working with the University of Alaska and industrial partners, Sandia has helped develop efficient and reliable energy sources for Arctic environments. Typically, residents of far northern villages rely on noxious, noisy diesel generators. Researchers envision utility companies that will place fuel cells in homes and operate them in a decentralized way. A small network of fuel cells in a village of several dozen homes would meet the need for heating and lighting throughout the winter. A distributed microgrid of fuel cells could avoid the risk of losing power during extreme cold snaps.

Sandia's partners in this initiative have included Northwest Power Systems LLC of Bend, Ore.; Energy Partners of West Palm Beach, Fla.; Plug Power of Latham, N.Y.; Teledyne Brown Engineering/Energy Systems of Hunt Valley, Md.; Schatz Energy Research Center of Humboldt State University in Arcata, Calif.; and Hydrogen Burner Technology of Long Beach, Calif.

Renewable Power: Let the Sun Shine In

Successful completion of the Solar II project holds promise that renewable energy — from the sun — may one day power major metropolitan centers.

An extension of Solar I, the Solar II project ended in April after reliably delivering large quantities of electricity to the power grid near Barstow, Calif. The achievement was made possible by using molten salt technology developed at Sandia to store solar energy

Mirrors at Sandia's solar tower are stowed in a horizontal position during high winds.

Above:
Chemist Tim Boyle combir
lithium with other metals
create cathodes for lithi
batteries.

so that it could be used even on cloudy days or at night. The Solar II plant delivered power 24 hours a day. Successful completion of the project set the stage for the next initiative: a 30-megawatt or larger plant for broader use.

Lithium Battery

Say good-bye to battery acid. Hello, electric cars.

If Sandia perfects the rechargeable lithium battery, the natural environment may be the biggest winner. Lithium batteries can be re-used, they don't produce

The Sky's the Limit: Sandia and Partners Go for Top Flight

ARM-UAV — The Atmospheric Radiation Measurement Unmanned Aerospace Vehicle — examines how clouds heat and cool the atmosphere.

DOE and Sandia have teamed with NASA, General Atomics, and the U.S. Navy to find out how clouds do what they do and improve models that predict climate change. Sandia provides technical leadership for the project. Key to the effort has been an unmanned

Right:
Unmanned aerial vehicles
have achieved record-bre
altitudes to study the ef
of cloud cover on climate
change.

being prepared *for* EMERGING

THREATS

Mark Tucker studies the effects of a non-hazardous foam that neutralizes biological poisons such as anthrax.

Microbes inside warheads, explosives inside letters, poison gas in subways — thus, conflict becomes localized, individualized. Once big and conspicuous, catastrophic weapons are today small and insidious. The almost personal nature of terrorism combines with its unpredictability to elevate the vulnerability of citizens living out their lives.

Finding what we can't see, expecting what we can't predict — though these are daunting challenges, Sandia has begun to meet them. Here is a sampling of technologies the laboratories have developed to combat a variety of emerging threats:

Above:
Like tiny dust mops, bees pick up airborne particles and chemicals. Beekeeper Gary Bender holds a frame of honeybees that could potentially detect land mines that kill or maim thousands of people each year.

Right:
Steve Casalnuovo reviews an enlarged computer printout of chemical sensors no bigger than a shirt button. The sensors are part of the µChemLab™ that detects chemical agents and explosives used in warfare and terrorism.

Structures That Weather the Storm

Whether a quake makes a building shiver or a flood fractures a dam, natural disasters turn artificial structures into death zones. Terrorist acts do the same.

Sandia is using technology to create buildings that protect, rather than harm, people. Our architectural surety program is a team effort with government agencies, professional associations, and universities to spot structural weaknesses, identify corrective designs, and improve building codes and construction standards.

Sandia uses computer simulation to study how structural elements — floors, roofs, foundations, windows — behave under stress. Modeling and simulation techniques developed over the past 50 years to make nuclear weapons safe, secure, and reliable are being applied to design structures that can survive catastrophe. In a project for the New Mexico Highway and Transportation Department, Sandia checked steel girders embedded in a concrete bridge to look for flaws and deterioration. Other initiatives include designing glass that, instead of splintering, converts to sand granules and determining how materials and floor plans affect the speed of fire traveling through a building.

Hand-Held Device to Foil Terrorists

A hand-held device called µChemLab™ allows technicians to perform analyses that once required laboratories staffed with PhDs.

µChemLab™ refers to a tiny chemical analysis laboratory housed in a device that is a little larger than a pocket calculator. The device contains multiple gas– and liquid-analysis laboratories within a hand–held device that is extremely accurate and has a low rate of false alarms. It is also rugged and is expected to complete 100 billion operations without failure. At the micron scale, fluid flow and viscosity are strongly influenced by molecular-level surface interactions.

These physical properties can be used in micron-scale inertial sensors that separate chemicals into micromachined channels with parts-per-billion accuracy.

A prototype of the device has successfully identified chemical agents used in warfare and terrorism and

various explosives and their degradation products. µChemLab™ separates a mix of chemicals into its constituents, isolating target compounds from the background and from one another. A tiny computer analyzes and identifies them; in about one minute, the computer displays a readout on the screen. The battery-operated µChemLab™ prototype will detect samples that weigh less than a single bacterium. Although the initial applications are in areas of national security, future uses in drug development, medical care, and environmental monitoring are not far behind.

Decontaminating Foam to the Rescue

How much safer the world would be if we could just wash our hands of chemical and biological weapons. Well, maybe we can.

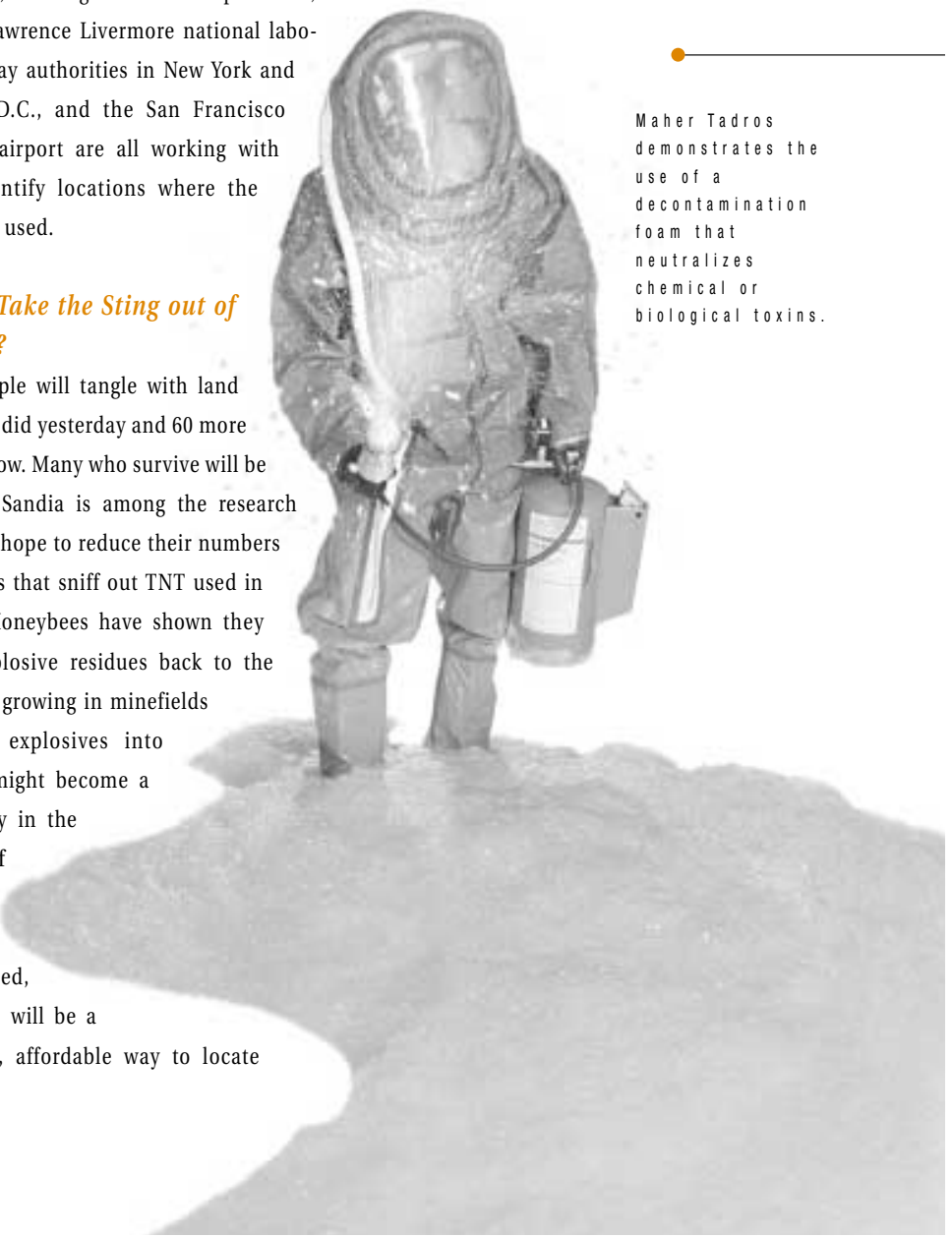
Sandia is developing a foam that works a lot like detergent lifting away an oily spot on a shirt. Harmless to people, the foam is toxic to anthrax and other spores. It neutralizes chemical compounds and snuffs out fire too. In comparison, existing decontaminates are expensive — as much as 10 times more costly — and are often hazardous or corrosive compounds.

If a terrorist released chemical or biological agents in a public place, the foam might be sprayed from a hand-held canister to decontaminate the area in minutes. Or in large public buildings, a sensor might trigger the fire sprinkler system to disburse the foam.

The U.S. Army, Los Angeles Police Department, Los Alamos and Lawrence Livermore national laboratories, subway authorities in New York and Washington, D.C., and the San Francisco international airport are all working with Sandia to identify locations where the foam might be used.

Could Bees Take the Sting out of Land Mines?

Today, 60 people will tangle with land mines — as 60 did yesterday and 60 more will do tomorrow. Many who survive will be handicapped. Sandia is among the research institutes that hope to reduce their numbers by raising bees that sniff out TNT used in land mines. Honeybees have shown they can carry explosive residues back to the hive. If plants growing in minefields absorb trace explosives into pollen, bees might become a kind of canary in the minefield. If researchers — and the bees — succeed, this technique will be a safe, effective, affordable way to locate buried mines.



Maher Tadros demonstrates the use of a decontamination foam that neutralizes chemical or biological toxins.

Swarms of fully self-contained, miniature autonomous vehicles are being developed to perform dangerous tasks such as locating and disabling land mines or detecting chemical and biological weapons. These one-cubic-inch machines may one day perform microsurgery or planetary exploration.

This Robot Paints by Numbers

"Bot" is not micro. But if it does its job well, no one can see Bot's art. Using a trio of robotic arms, Bot wields a paint sprayer.

The "painting" doesn't hang in a gallery — it hangs in the sky. It's an F-117 stealth fighter jet coated with a thin layer of radar-absorbent, blip-resistant paint, the handiwork of Bot.

Now, the numbers:

- A $5.7-million development project produced Bot, the largest intelligent system ever delivered by Sandia to an outside customer. That customer: the F-117 System Program Office, charged with maintaining these aircraft.
- Bot's canvas is 65 feet long with a 43-foot wingspan.
- Two 10,000-pound, rail-mounted robotic arms and one floor-mounted arm. One arm paints the jet top; a second paints the bottom; and the third paints removable parts.
- Two people can move Bot around the jet.
- Bot is projected to save the U.S. Air Force millions of dollars over the next four years.

Robug

Miniature, mobile vehicles may revolutionize surgery, space exploration, and surveillance just as miniature electronic circuits revolutionized computing. MARV, Sandia's Miniature Autonomous Robotic Vehicle, is the world's smallest. The self-sufficient device contains its own power, sensors, computers, and controls. It measures one cubic inch. With the exception of one of its Sandia-designed sensors, all of MARV's parts are commercially available and manufactured with standard machining techniques.

MARV's mission: To detect and follow buried wires emitting radio signals. This new technology is setting the pace for development of future miniature robots with enhanced mobility, on-board intelligence, and navigation and communication capabilities. Swarms of these devices may one day act cooperatively to locate and disable land mines or detect chemical and biological agents.

"Without Sandia and Chris, my job would be much more dangerous and the outcome on many render-safe scenes may not have been so favorable. I would like to encourage you and your organization to continue in this line of work since no one else seems willing to champion our cause."

— Charlie Johnson,
Houston Police Department Bomb Squad

From atop a 25-foot ladder, Larry Shipers adjusts a pair of cameras that provide feedback to a robotic painting system for the F-117 Nighthawk.

community outreach

THE NEXT EXPERTS

Sandia employee Juanita Sanchez plays patient for a young "ear doctor" at Christina Kent Day Care, a United Way agency in New Mexico.

Tomorrow's scientists and engineers — do they know who they are?

Maybe they don't. But today as they sit in middle- and high-school classrooms, mentors from Sandia are helping these youths plan their futures.

As part of Sandia's commitment to science and technology outreach, employees visit classrooms to give young people a peek at professional life — its realities, challenges, and rewards. They help students learn to read. They help them experience science. These are just a few of the 15 promises Sandia has made to youth as part of the national America's Promise campaign.

Students gain professional skills and experience on the job by teaming with researchers at the laboratories. Internship opportunities open doors to careers. Sandia has about 500 university students on roll during the year. That number increases during the summer months to about 800.

Sandia continues to hire recent college graduates to fill science and engineering positions as the laboratories revitalize an aging work force. During 1998, Sandia hired 300 technically qualified graduates from throughout the country and the local community to fill science and engineering positions, as well as 150 people to fill other positions. Current plans call for hiring 215 people to fill technical jobs in the coming year.

Research and recruiting go hand in hand when Sandia executives visit college campuses. Executives on loan — Sandians who lend expertise at colleges — not only interact with future scientists and engineers, they also spark research collaborations between government and academia. During 1998, Sandia spent $25.8 million on research collaborations with universities, $9.8 million of it in New Mexico.

To ensure educational success, Sandia has teamed with Albuquerque Public Schools, United Way of Central New Mexico, and Campfire Boys and Girls to increase the number of first-graders who can read and write at grade level. This pilot literacy program provides struggling readers with individual tutoring.

Lockheed Martin, which manages Sandia for the Department of Energy, sponsors scholarships for high school students who overcome adversity to succeed. Students are selected from dozens of schools in California and New Mexico, where Sandia's primary sites are located.

To promote cultural understanding and world peace, Sandians are helping the next generation of leaders reach out to their counterparts in Russia. Internet videoconferences have brought elementary-school students in New Mexico and California face to face with their

Second-grader Josh Brown and teacher Janet Sanchez read aloud a letter from a Russian pen pal.

Above:
Members of the Anthony Rael family enter their new Habitat for Humanity home for the first time.

Right:
Volunteer Toni Leon Kovarik works on the frame of a new house built by Sandia volunteers together with Habitat for Humanity.

"The Robotic Manufacturing Science and Engineering Laboratory at Sandia is "absolutely the best robotics facility in the world."

— Steve Charles, President, MicroDexterity Systems Inc.

pen pals in Snezhinsk. Energy Secretary Bill Richardson recently hosted a delegation of visitors from Snezhinsk at the dedication of a peace monument in Livermore, California. Through participation in such events, parents, students, and teachers forge personal bonds that will last a lifetime.

Investment Fuels Economic Growth

Sandia National Laboratories is a major contributor to the economy in New Mexico and other states. In fact, a recent study by New Mexico State University and the DOE showed that the impact of Sandia on New Mexico's economy is more than three times the value of the money that flows out of Sandia for salaries, purchases, taxes, and other expenses. This is because each of those dollars funds additional purchases and investment that promote economic growth.

During 1998, Sandia operations in New Mexico, California, and remote sites in Nevada, Hawaii, and Texas infused $513 million in payroll expenses, $700 million in purchases, $80 million in contract labor, $79 million in retiree benefits, and $50 million in health care expenses into regional economies. In New Mexico, $46 million went to women-owned small businesses, more than $72 million to small businesses described as "disadvantaged," and more than $11 million to educational institutions.

Business Park Advances Next-Generation Technologies

Created in 1998, the 300-acre Sandia Science and Technology Park is a cooperative initiative among Sandia, the City of Albuquerque, and several landowners. Funded by DOE, the state of New Mexico, and the city, the Park offers space for industries to establish sites near Sandia, the Albuquerque Conference Center, the University of New Mexico, and an international airport. A short drive away are the Los Alamos National Laboratory, five other state universities, and a number of high-technology industries.

EMCORE, a New Jersey-based company that expects to employ 250 people in the new business park, became the first tenant after building a 50,000-square-foot facility. Other new tenants are Microdexterity, which specializes in medical robotics for surgery, and CSTI, a telecommunications company. Key growth areas are optoelectronics, microelectronics, information technology, materials, biomedicine, and energy research.

The commercialization of new technologies developed at Sandia is nurtured by Technology Ventures Corporation, a company established by Lockheed Martin Corporation to help new businesses find venture capital. TVC has raised more than $134 million in venture capital and helped launch 32 new ventures that have created more than 1,200 new jobs.

Above:
Lockheed Martin Corporation donated, on behalf of Sandia, $1 million for a new theater at the New Mexico Museum of Natural History and Science. The theater will open to the public in early September 1999, with the showing of the movie, "Everest."

Employees Make A Difference

More than 2,000 Sandians, retirees, and their families volunteered more than 80,000 hours of personal time to nonprofit agencies during the year. Following are a few examples.

For 40 years, children in Albuquerque elementary schools have benefited from the annual Shoes for Kids campaign, which has provided more than 6,000 pairs of shoes. The 1999 effort raised more than $12,000 to purchase new shoes for 450 disadvantaged youngsters identified by their principals in 18 schools.

More than 700 Sandia volunteers contributed cash and sweat to build a new home for a struggling young family. They raised donations for building materials and built the home together with Habitat for Humanity, an international organization. During the 1998 Week of Caring, Sandia employees teamed with employees from local businesses and the United Way to spruce up and renovate Cuidando los Niños, an Albuquerque day care center for homeless children.

In California, Sandia volunteers spruced up the Family Crisis Center, worked with the Livermore Valley Humane Society, and assisted residents of the Pleasanton Senior Center. They collected food and gifts for 270 families during the annual Holiday Spirit Campaign.

Charitable Contributions Reach All-Time High

Over the years, the grand total of Sandia contributions to United Way is $32 million and rising. In 1998, New Mexico employees contributed $1.7 million, including $50,000 from Lockheed Martin. This not only made up one-fifth of all contributions to United Way of Greater Albuquerque, it represented 14 percent of all United Way contributions in New Mexico. In California, Sandians contributed a record $214,000 to Bay Area charities.

Society Benefits from New Technologies

When Sandia inventors receive top awards, America wins, too. Blue-ribbon technologies do more than serve lab goals; they often meet mainstream America's needs. Here are just a few examples from the past year:

Industry Week Selects Sandia Technologies as the Year's Best

Selected by *Industry Week* magazine as among the 25 most significant technologies of 1998:

- The photonic crystal of silicon or aluminum can bend infrared light, visible light, or microwaves around 90-degree corners without leaking any of the light. These devices may improve telecommunications and enable computers to use light energy instead of electricity. The winners: Shawn Lin, Jim Fleming.

- The Double Electron Layer Tunneling Transistor (also known as the quantum-well transistor), is predicted to operate at roughly 10 times the speed of the fastest transistor circuits now in use. The winners: Jerry Simmons, Jeong-Sun Moon, Mark Blount, Wes Baca, Sungkwun Lyo, John Reno, Michael Hatich, Joel Wendt.

International Competition Honors Research

R&D Magazine, in an international competition, honors the 100 most significant new technical products of the year. Sandians received six R&D 100 Awards in 1998 and 1999 for:

- SALVO, a software package that produces higher-quality seismic images for oil exploration. The winners: Curt Ober, David Womble, Louis Romero, Ron Oldfield, Robert Gjersen, with Conoco Inc. and Amerada Hess Corp.
- The photonic crystal *(see page 36)*.
- A room-temperature device for detecting X-rays and gamma rays and identifying the isotopes that emit them. The winners: Team leaders Ralph James and Jill Hruby, with Digirad Corp. and Carnegie Mellon University.
- LIVA, a technique for failure analysis from the back of an integrated circuit. The winners: Ed Cole, Jerry Soden, Dan Barton, Chris Henderson, Ted Dellin.
- Comrad, a field-portable system to characterize and monitor radiation using high-performance sensors and low power. The winners: Ralph James, Jim Lund, Richard Olsen, Eilene Cross, Bruce Brunett, John Van Scyoc.
- The Kikuchi Indexing and Simulation System that identifies phase changes as small as 0.1 micrometer using a scanning electron microscope. The winners: Joe Michael, Ray Goehner, Eric Schlienger.

Sandians Win Basic Energy Sciences Awards

The DOE honored three technologies:

- Self-assembly nanostructure for preparing mesoporous films and nanocomposites. The winners: Jeff Brinker and Alan Sellinger, with Yunfeng Lu, University of New Mexico, and Bruce Dunn and Jeff Zink, University of California at Los Angeles.

Above:
Alicia Lovato, granddaughter of Ernie Sanchez, looks at the remains of an aluminum plate that underwent solar thermal testing during the annual "Take Our Daughters to Work Day" at Sandia.

Left:
Jeff Brinker is a member of an award-winning team that created submicroscopic spheres for medical, industrial, and military applications.

Above:
Sometimes it's hard to tell if people are 17 or 70 at the annual picnic for Sandia retirees. This year's event commemorated Sandia's 50th anniversary and drew 1,800 retirees and their spouses.

Right:
Volunteer firefighter Keith Vollmer received Sandia's Shining Eagle award for community service. The award is given annually during National Volunteer Week.

- Continued research on how atoms move about on a surface. The winners: Gary Kellogg, Peter Feibelman.
- Biological microcavity laser for early detection of disease. The winners: Paul Gourley, Weng Chow, Mike Sinclair, Anthony McDonald.

DOE Recognizes Pollution Prevention

DOE honored a Sandia team for recycling solid waste to prevent pollution. The winners: Gabe King and staff, Kylene Molley, Jack Mizner, Corinne Willison.

Vice President Applauds Government Streamlining

Vice President Al Gore presented the Hammer Award to Don Larrichio for commercial practices that streamline the selection of contractors who provide goods and services.

Lockheed Martin Honors Innovation

Lockheed Martin Corporation's annual Nova Award went to two Sandia teams for:

- A new business partnership to accelerate next-generation microelectronics technology. This cooperative effort is using extreme ultraviolet lithography to produce microprocessors that are 100 times more powerful than those of today and memory chips that can store 1,000 times as much information. The winner: Rick Stulen, who is working with Lawrence Berkeley and Lawrence Livermore national labs, Intel Corporation, Advanced Micro Devices Inc., and Motorola Inc.
- Photonic crystal *(see page 36)*.

Distinguished Public Service

As a result of the commitment of Sandia and Lockheed Martin to community involvement, Sandia President Paul Robinson received the 1999 Distinguished Public Service Award for New Mexico.

A Private Place in Cyberspace

Sandia was a finalist for a *Discover Magazine* Award for Technological Innovation for the Microscopic Recodable Lock to prevent hackers from gaining access to computer files. The inventors: Larry Dalton and Frank Peter.

Sandia will officially reach its 50th birthday on Nov. 1, 1999, marking the day in 1949 when Sandia Corporation was created as a subsidiary of AT&T. The 50th anniversary emblem shows the two most common versions of the thunderbird — a mythical symbol from American Indian folklore — that Sandia has used as its corporate logo. The first version, in the lower half, was created by Sandia employee Clyde Walker in 1955. It remained essentially the same until 1970, when Sandia adopted the contemporary design that is bordered on four sides.